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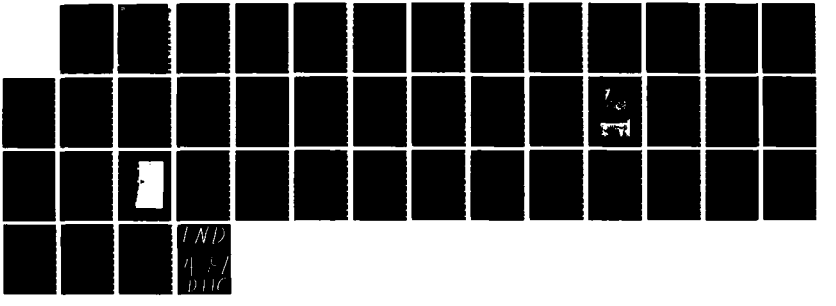

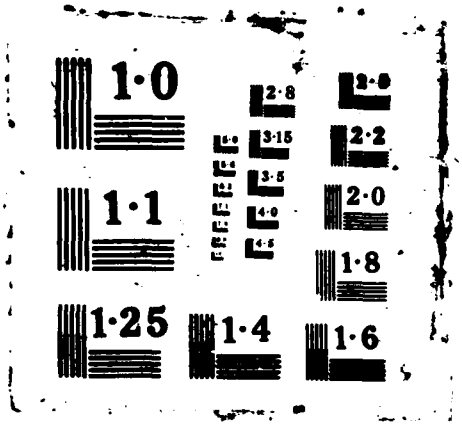
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Juniper Chaining:
A Vegetative and Soil Erosion Assessment of a Method of Rangeland Improvement on Fort Hood, Texas

by
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This report presents the results of an investigation conducted on Fort Hood, TX, during 1984-1985 to determine (1) the effect of mechanical chaining on the elimination of mature stands of Ashe juniper trees, (2) the natural re-establishment of herbaceous vegetation cover following chaining, and (3) the effects of chaining on soil erosion rates.

Results showed that chaining is effective in eliminating pure stands of juniper trees (99 percent canopy reduction) and is a viable option for increasing the amount of available training land while maintaining land resources. Thirteen months following chaining, the cover produced by the invasion of herbaceous plants (38 percent canopy cover) was sufficient to protect the soils from excessive erosion. However, caution should be exercised when chaining on slopes greater than about 5 to 10 percent or on shallow or other soils of low productivity.

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FOREWORD

This investigation was conducted for Fort Hood, TX, under IAO 380-85, dated 25 May 1985 and for the Office of the Assistant Chief, Headquarters, U.S. Army Corps of Engineers (HQUSACE) under Project (OMA funds) FAD No. 001126 dated 25 June 1985, "Condition and Trend Analyses." The work was performed by the Environmental Division (EN), U. S. Army Construction Engineering Research Laboratory (USA-CERL). The Fort Hood Project Monitor was Mr. Emmet Gray, and the OACE Technical Monitor was Mr. Donald Bandel, DAEN-ZCF-B.

The assistance of the following people in the research is gratefully acknowledged: John Aken, Charles Coffey, John Cornelius, Don Jones, John McConnell, Carrie Maenius, Valerie Morrill, and Regina Peterson; with special appreciation to Norman L. Dunbar and Willie Tschirhart (AFEN-DFE).

Dr. R. K. Jain is Chief of USA-CERL-EN. COL Norman C. Hintz is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

One of the main resources the Army needs to train effectively is land.[1] Currently, the Army does not have enough land for training; moreover, as technological advances in mobility and firepower are made, maneuver areas will effectively become smaller.[2] Thus, there is an urgent need to improve the "trainability" of Army lands while maintaining the land's environmental integrity.

Infestations of dense brush on Army lands, such as Ashe juniper (*Juniperus ashei*) on Fort Hood make maneuver training impossible, eliminates forage for cattle, and in pure stands, is of little value to wildlife. One example of this problem is the encroachment of Ashe juniper [*Juniperus ashei*] on Fort Hood, TX. Historically, Ashe juniper or cedar was largely restricted to shallow, rocky hillsides called "cedar brakes."[3] However, when prolonged overgrazing reduced the frequency of naturally occurring fires, Ashe juniper became established in fertile lowland sites.[4] As the juniper grew larger, the number of shrubs, forbs, and grasses declined.[5] In many areas, this species now forms nearly pure stands with a closed canopy and a complete litter layer. Juniper litter also has an allelopathic effect on many grasses.[6] One method of reducing dense juniper stands is chaining. This method of land improvement is evaluated in this report.

Objective

The objectives of this study were to: (1) evaluate the effectiveness of mechanical chaining in eliminating mature stands of Ashe juniper, (2) evaluate the natural establishment of vegetation following chaining, (3) estimate the effects of chaining on soil erosion rates, and (4) establish a general database to increase understanding of rangeland improvement programs.

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[1] TC 25-2, *Training Ranges* (Department of the Army [DA], 10 March 1980).

[2] TC 25-1, *Training Land* (DA, 4 August 1978).

[3] C. J. Scifres, *Brush Management: Principles and Practices for Texas and the Southwest* (Texas A&M University Press, 1980), pp 1-360.

[4] R. L. Wink and H. A. Wright, "Effects of Fire on Ashe Juniper Community," *J. Range Management*, Vol 26 (1973), pp 326-329.

[5] H. W. Springfield, "Characteristics and Management of Southwestern Pinyon-Juniper Ranges: The Status of Our Knowledge," *USDA Forest Service Res. Pap. 160* (U.S. Department of Agriculture [USDA], Rocky Mt. Forest and Range Exp. Station, 1976).

[6] F. Lavin, D. A. Jameson, and F. B. Gamm, "Juniper Extract and Deficient Aeration Effects on Germination of Six Range Species," *J. Range Management*, Vol 21 (1968), pp 262-263.

Approach

Study plots were established in three areas where juniper was recently chained. Ground and canopy cover and botanical composition were surveyed over a 2-year period to provide data on vegetative dynamics. Soil erosion estimates were then obtained from these data and from slope (gradients and lengths) and soil texture analyses. The information collected was then analyzed. This report is the first in a series evaluating the effectiveness of various rangeland improvement practices.

Scope

This report does not determine the number of acres of juniper or other brush on Fort Hood that should be chained. Also, it does not assess the impact of chaining on wildlife populations or archaeological sites.

Mode of Technology Transfer

It is recommended that the methodologies provided in this report for evaluating land restoration programs be incorporated into Army Technical Manual 5-630, *Army Natural Resources Land Management.*

2 SITE DESCRIPTION

Fort Hood and Surrounding Region

Fort Hood encompasses about 87972 ha (Figure 1*) and is about 43 km at its greatest length (north-south) and nearly 42 km at its greatest width. Fort Hood is located in Coryell and Bell counties in central Texas in the southeast corner of the Cross Timbers and Prairie Vegetation area.[7] This region comprises a large area (about 6.9 million ha) of closely associated prairie and woodland sites.[8] Topographically, it is rolling to hilly, with rapid surface drainage. Sharp changes in the vegetation are associated with differences in soils and topography. Fort Hood generally slopes from west to east, ranging in elevation from about 190 to 370 m. Cowhouse Creek and Owl Creek drain most of the installation; both empty into Belton Reservoir along the eastern border of the installation. Average annual precipitation at Gatesville (Table 1), which is about 16 km north of the study site, is 826 mm. Precipitation peaks in April, May and June (34 percent of the annual amount), and is lowest during January, February, and March (about 19 percent of the annual amount). The average amount of rainfall is slightly higher on east Fort Hood than on the western side of the installation.

Fort Hood was opened in 1942 and is now the home of the 1st Cavalry and 2nd Armored Divisions. The 49th Armored Division of the Texas National Guard and their host groups use North Fort Hood. Until mid-1954, the installation was open range for grazing; after that, the grazing rights for most of the installation were leased by the Central Texas Cattleman's Association.[9]

Study Sites

Three study sites (Figure 2) located in Training Areas 65 and 66 on north-central Fort Hood along the southern boundary of Owl Creek Road were chosen as study plots. Each site appeared to have been tilled until the Army purchased Fort Hood in 1942. Thus, the chained cover probably represented about 42 years of plant succession (Figures 3 and 4).

Total precipitation in 1984 was 207mm below average and 207 mm above average in 1985 (Table 1). Precipitation was below average during the latter half of the 1984 growing season, but well above average during the first half of the 1985 growing season.

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*Figures and tables are located at the end of the report (see p 21).

[7] F. W. Gould, *The Grasses of Texas* (Texas A&M University Press, 1975), pp 1-653.

[8] Scifres.

[9] "Operation Round-up on at Hood," *The Gatesville Messenger*, Vol 17 (1954).

3 METHODS

The three study sites were chained in mid-June of 1984 when soil moisture was low. The chaining operation consisted of dragging a heavy anchor chain, about 55 m long, in a loop behind two D-7 crawler tractors. Swath width was approximately 18 m. The anchor chain weighed about 107 kg/m. Several oak trees that occurred within the stand of juniper were purposely avoided when chaining.

Topographic, soils, vegetative cover, botanical composition, and erosion data were collected from the study sites during 18-19 July 1984 and 15-16 July 1985.

Topography

Topographic analyses were conducted to estimate soil erosion rates, and thereby help determine the effect of chaining on erosion rates. Both the length and the steepness (gradient) of the land substantially affect the rate of soil erosion by water. Slope length (L) was measured in the field to the nearest 1.0 m, and slope gradient (S) was measured to the nearest 0.1 percent.

Slope gradient was measured with a Suunto clinometer. Slope length at each sample point was measured as the straight-line distance from the origin of overland flow to where runoff enters a defined channel (concentrated water flow) or to where a marked change in slope occurs. Slope gradient and length were measured at the beginning and end of each 100-m transect segment. On the middle and western study sites (Figure 2), where 200-m transects were established, slope measurements were the same for the end of the first 100-m transect and the beginning (0 m) of the second 100-m transect. Eight slope gradients and eight slope lengths were measured.

Soils

Soils data were obtained to determine their erodibility. Two soil samples were taken from along each transect at the 25- and 75-m points. These samples (10 for the study) were collected with a soil auger from the top 150 mm of the soil, and then bagged, labeled, and analyzed for pH. Soil texture analyses were calculated using the wet-sieve and hydrometer methods.

Vegetative Cover and Botanical Composition Data

Vegetative cover and the botanical composition were analyzed to determine how quickly and to what degree vegetation establishes itself after chaining. On 18-19 July 1984, one 200-m line transect was established in each of the three study sites (shown as 9, 10, and 11 in Figure 2). The beginning of each transect was located in an area that appeared to be representative of the topography and vegetative cover. The areas were permanently identified by stake, photographs, and compass bearing (Suunto sighting compass) on easily recognizable nearby landmarks. The direction of each transect was randomly established and recorded by compass bearing. Nine 0.6-m-long stakes were hammered into the ground along each transect at 25-m intervals until only 20 mm remained exposed. For ease of data calculations, each transect was divided into two 100 m segments. The first 100 m segment was labeled transect "a," and the last 100 m was labeled transect "b." A subsequent assessment of transect 9a indicated that unlike in

the other transects, the pre-chained juniper cover had not formed a closed canopy and grass cover occurred in the interspaces. Transect 9a was therefore omitted. All data calculations reported are for transects 9b, 10a, 10b, 11a, and 11b.

Ground and canopy observations were made by the point-intercept method at 1-m intervals along each line transect (100 observation points per transect). Ground cover variables (horizontal measures) recorded were bare ground, gravel (10.0 to 20.0 mm), rock (> 20 mm), litter (≤ 10 mm in at least two dimensions), deadwood (> 10 mm in at least two dimensions), and vegetative basal (crown) cover (by species). Canopy cover (vertical measures), defined as vegetation not in contact with the ground, was recorded, by species, at each 0.1-m height interval to 1.99 m where vegetation touched a narrow (7-mm diameter), vertically positioned measuring rod. Vegetation 2.0 m tall and above was recorded at each 0.5-m interval where vegetation touched a 50-mm-diameter measuring rod. Means of all variables were calculated for each 100-m line transect.

Scientific and common names of all plants follow Correll and Johnston,[10] except that the common name "live oak" is used in place of "scrub live oak."

Erosion Estimates Data

The Universal Soil Loss Equation [11] (USLE) was used to estimate soil erosion. The R value (rainfall and runoff factor) for the study sites was 280.[12] Values for K (soil erodibility factor) are of the surface horizon and were calculated using the Soil Erodibility Nomograph.[13] The influence of gravel and rock fragments on soil erodibility was accounted for in the C (cover) factor.[14] The L and S values (slope length and gradient) were measured in the field to the nearest meter and to the nearest 0.1 percent, respectively, as explained on p 10.

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[10] D. S. Correll and M. C. Johnston, *Manual of the Vascular Plants of Texas* (Texas Research Foundation, 1970).

[11] W. H. Wischmeier and D. D. Smith, *Predicting Rainfall Erosion Losses—A Guide to Conservation Planning*, Agriculture Handbook No. 537 (USDA, 1978), pp 1-58.

[12] U.S.D.A. Soil Conservation Service, Texas Office.

[13] *Predicting Rainfall Erosion Losses—A Guide to Conservation Planning.*

[14] J. R. Simanton, H. B. Osborn, and K. G. Renard, "Application of the USLE to Southwestern Rangelands," *Proc. Ariz. Sec. Am. Water Resource Assoc. Hydrol. Sec., Ariz. Acad. Sci.*, Vol 10 (1980), pp 213-220.

4 RESULTS

Topography

Each of the three study sites was a swale with gradually increasing elevations to either side. Each site was drained by a small, centrally located gully. Drainage was to the north on each site. Ten slope gradients were measured (two from each 100-m transect at the 25- and 75-m points), ranging from 0.8 to 4.9 percent, with an average gradient of 3.1 percent. Ten slope lengths were measured and these ranged from 90 to 140 m long (average of 110 m).

Soils

The soil survey of Coryell County[15] indicates that the soils of all three study sites are of the Krum series. However, textural analyses (Table 2 and Figure 5) show that the clay content of the surface horizon is less than 40 percent (Krum soils are more than 40 percent) and that the textural class is typically clay loam (generally silty clay for Krum soils); therefore, all soils are referred to as Lewisville clay loam soils. Lewisville soils are typically deep and well-drained, with moderate permeability and high available water capacity. Analyses of soil pH (Table 2) illustrate that the soils are slightly alkaline, ranging from 8.00 to 8.45. The Lewisville soil series is a component of the clay loam range site, which has a potential climax plant community of tall perennial grasses (true prairie). The Soil Conservation Service considered the soil erosion factor (K from the USLE) to average 0.32.[16] However, calculations of K using the Soil Erodibility Nomograph[17] yielded an average of 0.21 (Table 2), and this latter value is used here to estimate soil erosion rates. Maximum allowable soil loss (T) for Lewisville soil is 5.00 tons/acre/year.[18]

Vegetative Cover

Ground Cover

A visual examination of unchained stands of juniper adjacent to the chained study sites in 1984 revealed that the entire surface of the ground appeared to be covered with juniper leaf litter. No plants were observed under the closed juniper canopy.

In 1984, about 1 month after chaining, total ground cover was about 68 percent (Table 3). Juniper litter comprised most of the cover (56 percent), and nonjuniper litter accounted for 1 percent of the ground cover. Deadwood (all from junipers) accounted for about 9 percent, and gravel, rock, and cowchips together accounted for less than 2 percent of the ground cover. There was no crown (basal) cover. Of the 32 percent bare ground, most (25 percent) was exposed (having no canopy over it) and 7 percent had a canopy over it.

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[15] *Soil Survey of Coryell County, Texas* (Soil Conservation Service, 1985).
[16] *Soil Survey of Coryell County, Texas.*
[17] *Predicting Rainfall Erosion Losses--A Guide to Conservation Planning.*
[18] *Soil Survey of Coryell County, Texas.*

One year later in July 1985, there was no significant change in total ground cover (a 2 percent increase from 68 to 70 percent). Also, there was no significant change in any of the ground cover variables, except deadwood, which decreased significantly ($P < 0.05$), from 9 percent in 1984 to 1 percent in 1985. Although not significant, a 1 percent crown cover was present in 1985, that had not been observed in 1984. It is important to note that although the amount of total bare ground did not change from 1984 to 1985, the portion of exposed bare ground decreased significantly (25 to 12 percent, $p < 0.001$) and canopied bare ground increased significantly (7 to 17 percent, $p < 0.001$). Figure 6 shows the minor change in total ground cover (July 1984 to July 1985), along with the major changes in total canopy cover for each of the five 100-m transects.

Canopy Cover

Juniper Canopy Cover. Before chaining, the juniper stand was even-aged, averaging about 4.5 m in height with a closed canopy. These stands were impossible to walk through and at lower levels the branches were completely dead since light was unable to penetrate the canopy.

In 1984, about 1 month after chaining, all juniper cover was within 1.6 m of the ground's surface. A breakdown of juniper cover in 0.1-m height increments above the ground (Table 4) revealed that cover was most dense within 0.3 m of the surface (about 10 to 14 percent canopy cover for each 0.1-m height interval). Above 0.3 m, cover decreased gradually from 6 percent (0.4-m height interval) to less than 1 percent at intervals 1.3 to 1.6 m above the soil surface. Total canopy cover for juniper was 34.2 percent, of which only 1 percent was live (Figure 7). Note that total juniper canopy cover is much less than the sum of canopy cover for all height intervals, because a portion of each canopy layer overlaps with part of the canopy of other layers.

Twelve months later, juniper cover had decreased within each 0.1-m height interval, but these differences were not significant (Table 4). However, total juniper canopy cover decreased significantly ($P < 0.05$), from 34 to 25 percent. Of the 25 percent juniper canopy cover, approximately 3 percent was live (Figure 5) and 22 percent was dead.

Nonjuniper Canopy Cover. Before chaining, no forbs and grasses were observed under the juniper canopy. Several small live oak trees (*Quercus fusiformis*) were observed intermingled in the juniper canopy.

After chaining, in July 1984, nonjuniper canopy cover was virtually absent. In fact, all 0.1-m height intervals contained less than 1.0 percent canopy cover (Table 5 and Figure 8). At 2 m and above in height, all 0.5-m intervals also contained less than 1.0 percent canopy cover per layer. Total nonjuniper canopy cover averaged 1.4 percent.

In July 1985, there was a significant increase in nonjuniper canopy cover for each layer from 0.1 to 0.8 m above the surface of the ground (Table 5 and Figure 8). Each 0.1-m height interval below 0.8 m contained more than 1.0 percent canopy cover; of these, the lower three layers contained about 10 percent (0.3-m height interval) to 14 percent (0.1-m height interval) canopy cover. Above 0.8 m, there were no significant changes in nonjuniper canopy cover. However, total nonjuniper canopy cover increased significantly ($P < 0.001$), from an average of 1.4 percent in 1984 to 38.2 percent in 1985.

Juniper and Nonjuniper Canopy Cover Combined. In 1984, 1 month after chaining, most canopy cover was within 0.3 m of the ground's surface (Table 6). These lowest

three height intervals contained most of the cover--11.2 percent (0.1-m height interval), 13.6 percent (0.2-m), and 11.6 percent (0.3-m). Above 0.3 m, total canopy cover gradually decreased from 6.0 percent (0.4-m height level) to less than 1.0 percent in areas higher than 1.2 m. Total canopy cover averaged 35.4 percent.

In July 1985, the amounts of cover at each of the lower 0.3-m height intervals increased significantly (0.1 m, 11.2 to 24.6 percent, $P < 0.001$; 0.2 m, 13.6 to 23.6 percent, $P < 0.001$; 0.3 m, 11.6 to 17.4 percent, $P < 0.01$). There were increases in canopy cover at higher intervals, but none of these increases were significant (Table 6). Total canopy cover showed a significant increase, from 35.4 to 62.4 percent ($P < 0.001$). Figure 9 illustrates the changes in the amounts of cover at the first ten 0.1-m height intervals (to 1-m) between 1984 and 1985.

Botanical Composition

Life Forms

Before chaining and 1 month after chaining, two species of trees were present: Ashe juniper and live oak. Buffalo grass (*Buchloe dactyloides*), a perennial, was also observed.

One year later in July 1985, 25 species of plants were recorded (Table 7). Of these, two were trees (Ashe juniper and live oak), three were grasses (Texas grama [*Bouteloua rigidiseta*], buffalo grass, and hairy tridens [*Erioneuron pilosum*]), one was a vine (white honeysuckle [*Lonicera albiflora*]), and 19 were forbs. Of the forbs, 11 were annuals (two species of croton [*Croton monanthogynus* and *Croton texensis*], prairie euphorb [*Euphorbia missurica*], pasture heliotrope [*Heliotropium tenellum*], prickly lettuce [*Lactuca serriola*], crownseed [*Pectis angustifolia*], redseed plantain [*Plantago rhodosperma*] common broomweed [*Xanthocephalum dracunculoides*], lemmon beebalm [*Monarda citriodora*], cocklebur [*Xanthium strumarium*], and narrowleaf sumpweed [*Iva angustifolia*]), and eight were perennials (prairie bundleflower [*Desmanthus leptolobus*], prairie bluet [*Hedyotis nigricans*], plains black-foot [*Melampodium leucanthum*], Texas salvia [*Salvia texana*], Dakota vervain [*Verbena bipinnatifida*], *Hedeoma drummondii* [no common name], slender greenthread [*Thelesperma simplicifolium*], and western ironweed [*Vernonia baldwinii*]). No shrubs were recorded.

Relative Canopy Cover by Species

Relative canopy cover does not identify changes in total canopy cover with time, but it does document the contribution of each species to total cover. In this study, it is possible to quantify and visually illustrate changes in the contribution of each species to total cover within space and time.

In 1984, about 1 month after chaining, dead juniper accounted for 87 to 100 percent of total cover at each 0.1-m height interval (Figure 10). Live juniper accounted for an additional 0 to 8 percent of total cover at each of these height intervals. Together, dead and live juniper comprised about 92 to 100 percent of all cover at each 0.1-m height interval. Grasses and forbs were present only at the 0.1-m height interval and contributed about 7 percent to total cover. Several small live oak trees (purposefully avoided during the chaining operations), which were intercepted at the 0.5-m and 1.0-m height intervals, contributed about 3 percent and 7 percent, respectively, to total cover at each of these intervals. There were 25 plant intercepts ("hits") above 1.0 m, all between 1.1 and 4.5 m; of these, 21 intercepts were dead juniper, and four were live oak.

In 1985, about 13 months after chaining, dead and live juniper made up less than 60 percent of total cover at most heights (Figure 11). At the lower heights (0.1 to 0.3 m), juniper accounted for about 35 to 40 percent of total cover. Grasses and forbs were present at all height intervals through 1.0 m. At lower heights, primarily 0.1 to 0.3 m, herbaceous vegetation accounted for about 60 percent of total cover. At these heights, two species of croton, vervain, black-foot, and bluet were particularly common, contributing about 35 to 50 percent of total cover at each height interval.

At higher intervals, particularly 0.5 to 0.9 m, broomweed and lemmon beebalm accounted for about 25 to 40 percent of total cover. Common broomweed accounted for about 25 to 35 percent of total cover at the 0.5- to 0.9-m height intervals. About 16 other species of grasses and forbs made up about 35 percent of total cover at the 0.1-m level and less than 15 percent of total cover at each of the higher intervals. There were 10 hits above 1.0 m, all between 1.1 and 4.0 m; of those, seven were dead juniper and three were live oak.

Soil Erosion Estimates

The primary factors influencing soil erosion are (1) rainfall intensities and amounts (R factor of the USLE), (2) soil erodibility, which is largely a product of soil texture (K factor of the USLE), (3) steepness of the land in combination with slope length (LS factor of the USLE), and (4) the amount of ground and canopy cover available to protect the soil from raindrop impact and surface water runoff (C factor of the USLE). In general, erosion increases as (1) and (3) above increase, as (4) decreases, and as the soils (2) increase in silt.

As noted on p 11, R for Coryell County is 280, K as determined from soil samples is 0.21 (Table 2), LS is 0.51 (Table 8), and the vegetation cover before chaining was estimated at 100 percent for canopy cover and 100 percent for ground cover (almost all juniper litter cover), yielding a C of 0.01. The estimated soil erosion rate for the sites before chaining is therefore, 280 x 0.21 x 0.51 x 0.01, which is equal to 0.30 tons/acre/year of soil erosion (Table 9).

One month after chaining in 1984, vegetation canopy cover was reduced to 68 percent and ground cover to 35 percent, yielding a C of 0.06. Thus, soil erosion had increased sixfold to 1.80 tons/acre/year (280 x 0.21 x 0.51 x 0.06 = 1.80 tons/acre/year) due to the immediate effects of chaining. However, this amount of cover was still adequate to keep soil erosion rates below the allowable limit of 5.00 tons/acre/year. One year later in July 1985, vegetative canopy cover increased to 70 percent and ground cover increased to 62 percent, yielding a C of 0.05. This increase in cover reduced soil erosion from the 1.80 tons/acre/year calculated in July 1984 to 1.50 tons/acre/year (280 x 0.21 x 0.51 x 0.05 = 1.50 tons/acre/year).

5 DISCUSSION

Change in Vegetation Cover

Ground cover before chaining was about 100 percent. Most of the ground cover was made up of juniper leaf litter. The immediate effect of chaining was to reduce total ground cover to 68 percent. This increase in bare ground was due to the exposure of subsurface soil when the roots were ripped from the soil. By July 1985, ground cover had increased to 70 percent. It may require several years for ground cover to increase significantly and much of this increase will likely be from litter accumulation. Grasses, which accumulate litter much more quickly than forbs, could possibly be seeded aerially if forage production for grazing is required.

Canopy cover of juniper before chaining was about 100 percent. Chaining was extremely effective in eliminating live juniper cover. Immediately after chaining (July 1984), juniper cover was reduced to 35 percent with about 1 percent remaining alive and 33 percent dead. Forb and grass cover was essentially absent (1 percent). Twelve months later in July 1985, juniper cover was further reduced to 25 percent, with about 3 percent live and 22 percent dead. Forb and grass canopy cover greatly increased from 1 percent to about 38 percent (Figure 12). From July 1984 to July 1985, total canopy cover increased from 35 to 62 percent.

Change in Botanical Composition

Before chaining, the site consisted of a dense cover of juniper with a few live oak trees interspersed among the juniper crowns. It was impossible to walk through the woodland and assess the understory, but visual observations indicated that an understory was essentially absent. The first quantitative survey conducted immediately after chaining confirmed that a plant understory was essentially absent. Only one observation of buffalo grass and two unidentifiable dead forbs were observed on the three study sites.

In July 1985, species diversity increased to 25. All of the new species were forbs, except for one vine (white honeysuckle) and two grasses (Texas grama and hairy tridens). Of the 19 forbs, 11 were annuals and eight were perennials. No shrubs were recorded. Two species of croton, bluet, vervain, and black-foot made up most of the low (0.1 to 0.3 m) herbaceous cover, while broomweed and beebalm made up most of the higher (0.4 to 0.9 m) herbaceous cover (Figure 9).

In a study of chained redberry juniper (*Juniperus pinchotii*), Ueckert, et al.,[19] reported that production of native grasses and forbs did not increase the first year after removal of mature juniper. However, they attributed this to below-normal spring rainfall and the low range condition on the study area. No information could be found on the vegetational response to chaining of Ashe juniper. Rippel, et al.,[20] reported that although many areas have been chained, few have been evaluated for vegetational response to the treatment.

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[19] D. N. Ueckert, S. G. Whisenant, D. C. Landford, and V. Polochek, "Control of Redberry Juniper Seedlings," *Rangeland Resources Research*, Consolidated Progress Report 3665 (Texas Agricultural Experiment Station, 1980), pp 1-112.

[20] P. Rippel, R. D. Pieper, and G. A. Lymbery, "Vegetational Evaluation of Pinyon-Juniper Cabling in South-Central New Mexico," *J. Range Management*, Vol 36, No.1 (1983), pp 13-15.

Change in Soil Erosion Rates

Soil erosion estimates using the USLE indicate that soil erosion rates at all stages, both before and after chaining, are within acceptable limits of soil loss tolerances (5.00 tons/acre/year).

Williams, et al.,[21] and Gifford, et al.,[22] reported differences in water infiltration and sediment rates at random points between 28 chained and 28 nearby unchained pinyon-juniper sites in Utah. Results indicated that conversion of these woodlands to grasslands did not necessarily increase infiltration rates or reduce sediment yields.

Chaining on slopes greater than about 5 to 10 percent or on soils less productive (shallow, rocky soils) than the ones evaluated here should be monitored closely for signs of excessive soil erosion.

Effectiveness of Chaining

Ashe juniper is not susceptible to broadcast applications of phenoxy herbicides normally used for range improvements.[23] Chaining is the most recommended practice for controlling stands of juniper. It is particularly recommended where trees do not exceed 18 in. in diameter and population density does not exceed 1000 plants per acre.[24] These figures will vary, depending on tractor size and width of the swath.

Chaining alone generally offers only temporary benefits to brush problems. To prolong the life of the original mechanical chaining treatment, fire has been used as a follow-up treatment. The uprooting of Ashe juniper trees during the chaining process brings the chained juniper cover close to the surface of the ground, leaving it accessible to fire. Also, the young juniper trees (less than about 2 m in height) that become established after chaining are easily killed by fire. Wink and Wright found that during a dry spring, where the amount of fire fuel was 1000 kg/ha, 99 percent of the chained Ashe juniper cover (piles from chaining) was consumed and 99 percent of the young juniper trees less than 1.8 m tall were killed by headfires. If it takes 15 years for seedling juniper to grow to 2 m tall, then burning on a 15-year cycle is adequate to control juniper.

Soil moisture is a primary consideration before conducting a burn. With good soil moisture, plants can begin to grow immediately after the burn, recovery is rapid, and soil erosion is minimal. Williams, Gifford, and Coltharp found that on chained pinyon-juniper sites in Utah, water infiltration and erosion were strongly affected by the percentage of bare soil surface and by plant crown cover. Other parameters that are important to consider before burning are wind speed, air temperature, and relative humidity. Wink and Wright recommended burning Ashe juniper during wind speeds of 16 km/hr, an air temperature of 23°C, and relative humidity of 28 percent.

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[21] G. Williams, G. F. Gifford, and G. B. Coltharp, "Infiltrometer Studies on Treated Vs. Untreated Pinyon-Juniper Sites in Central Utah," *J. Range Management*, Vol 22 (1969), pp 110-114.

[22] G. F. Gifford, G. Williams, and G. B. Coltharp, "Infiltration and Erosion Studies on Pinyon-Juniper Conversion Sites in Southern Utah," *J. Range Management*, Vol 23 (1970), pp 402-406.

[23] Scifres.

[24] Scifres.

Burning is reported to increase yields of little bluestem [25] (*Schizachyrium scoparium*); however, Texas wintergrass (*Stipa leucotricha*) will not tolerate burning. Spring fires kill many undesirable forbs such as common broomweed. However, some brush species, such as flame-leaf sumac (*Rhus lanceolata*), respond very favorably to burning.

[5] Wink and Wright.

6 CONCLUSIONS

Chaining is an effective management tool for eliminating mature, pure stands of Ashe juniper. Juniper stands having a near 100 percent canopy cover were reduced to about 1 percent live cover 1 month after chaining. One year later, Ashe juniper cover remained low (3 percent live). In 1985, all live juniper cover was within 0.8 m of the ground's surface, leaving it easily controlled by follow-up burning.

The natural establishment of herbaceous vegetation (secondary succession) following chaining was rapid and botanically diverse. One month after chaining, there was less than 1 percent herbaceous canopy cover, but 12 months later, herbaceous canopy cover had increased to 38 percent. The number of identified herbaceous species increased from one to 22 over the same time period. Nineteen of the 22 herbaceous plant species recorded in 1985 were forbs (three were grasses); about half were annuals and half perennials. One year after treatment, the vast majority of the herbaceous cover was made up of four annual forbs (common broomweed, lemmon beebalm, and two species of croton) and three perennials (prairie bluet, Dakota vervain, and plains blackfoot).

Estimates of soil erosion rates using the USLE indicate that chaining does not increase soil erosion beyond acceptable limits (5.00 tons/acre/year). Estimated erosion rates averaged 0.30 tons/acre/year, before chaining, 1.80 tons/acre/year, 1 month after chaining, and 1.50 tons/acre/year 12 months later.

The information collected during this study will increase understanding of the effects of mechanical chaining, provide information to resource managers for formulating land management decisions, and serve as a database for assessing future changes in soil and cover resources.

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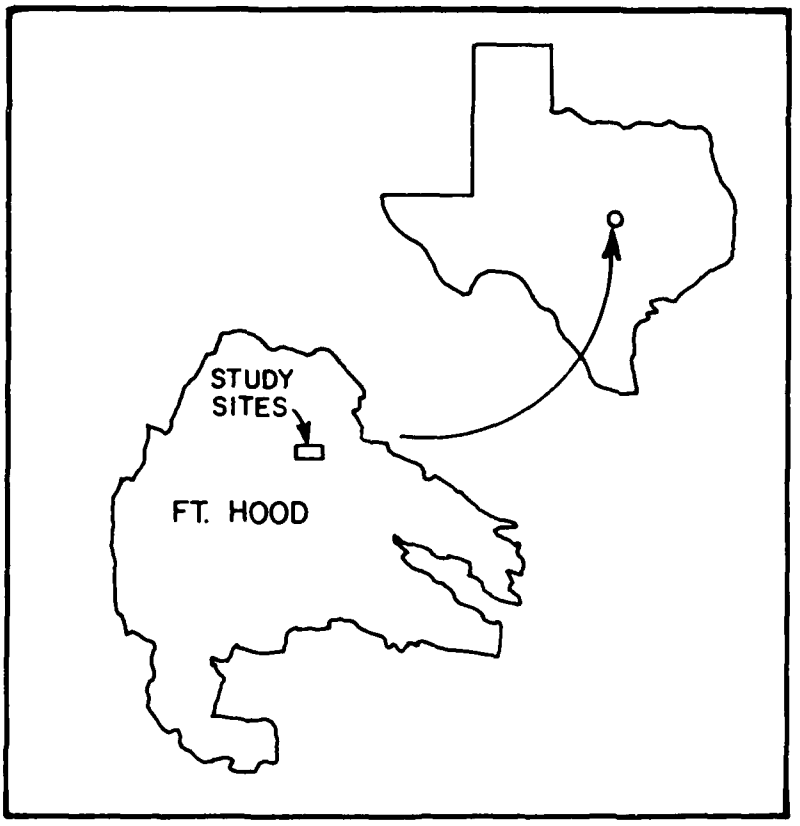

Figure 1. General location map of Fort Hood and the study sites.

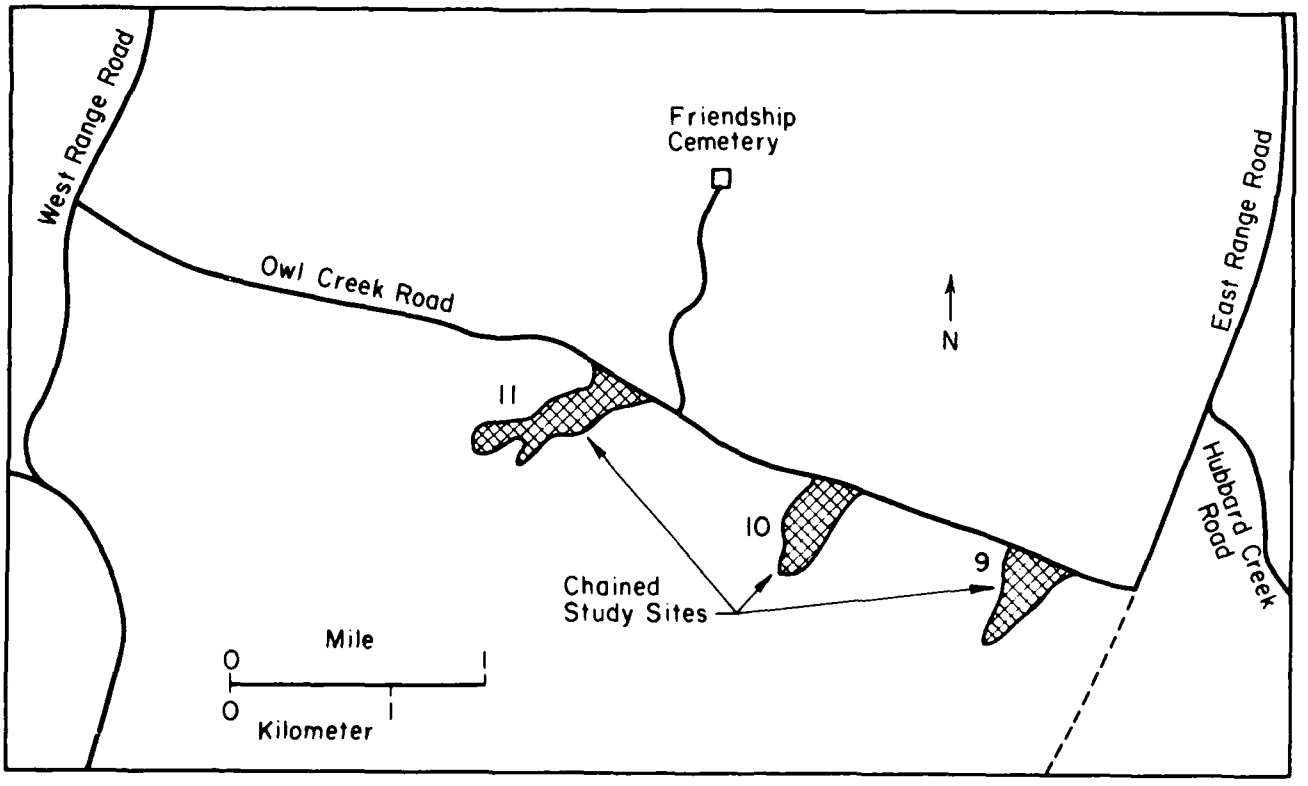

Figure 2. Location of the three chained study sites on Fort Hood, TX.

Figure 3. Aerial photograph showing the dense, even-aged stand of chained Ashe juniper about 1 month after chaining.

Figure 4. Photograph of a site about 1 month after chaining.

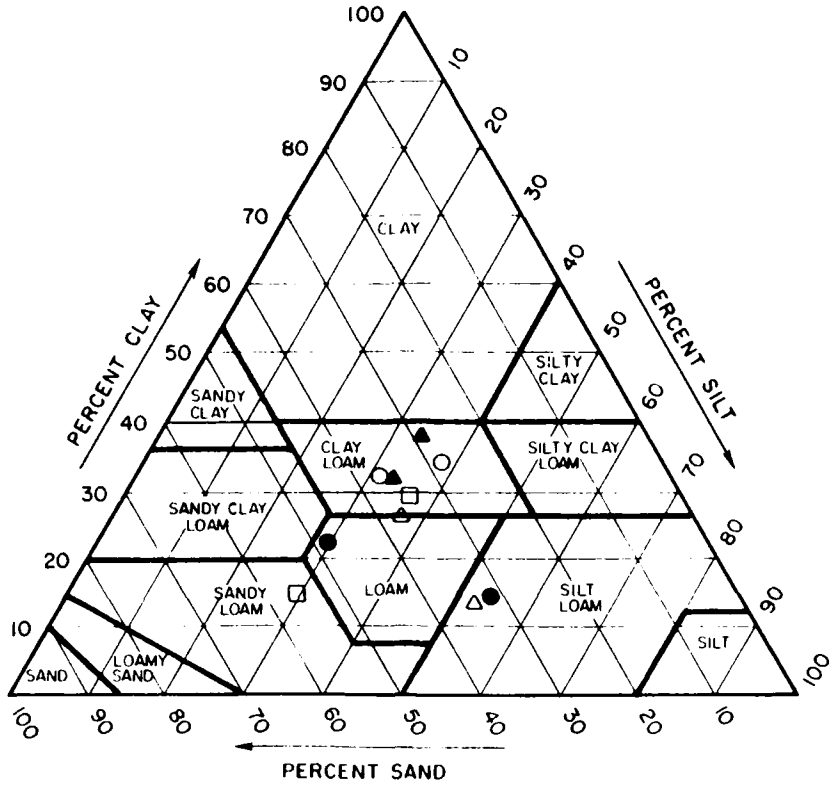

Figure 5. Soil particle size distribution of the study sites. Symbols represent soil samples from transects 9b (squares), 10a (solid circles), 10b (open circles), 11a (solid triangles), and 11b (open triangles).

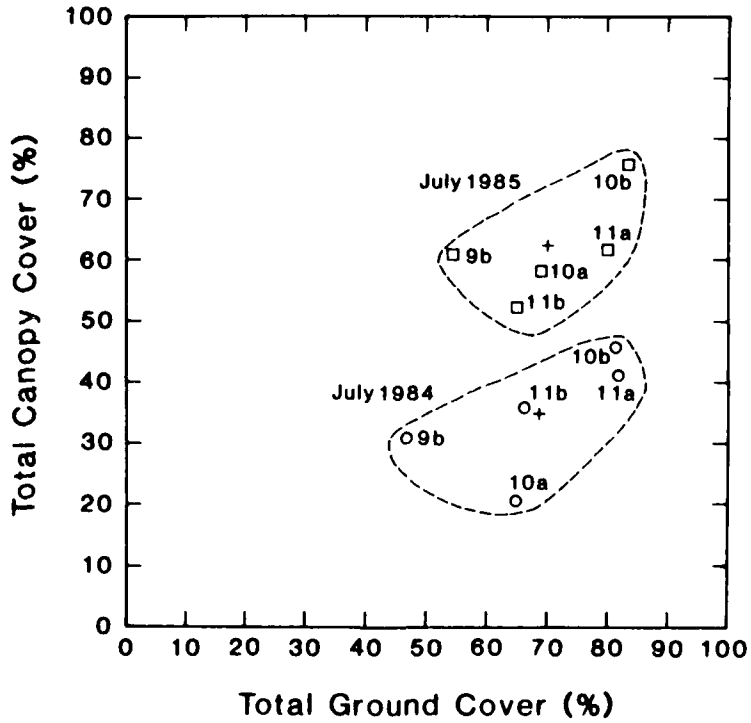

Figure 6. A comparison of changes in total ground cover and total canopy cover for each of the five transects 1 month after and 13 months after chaining.

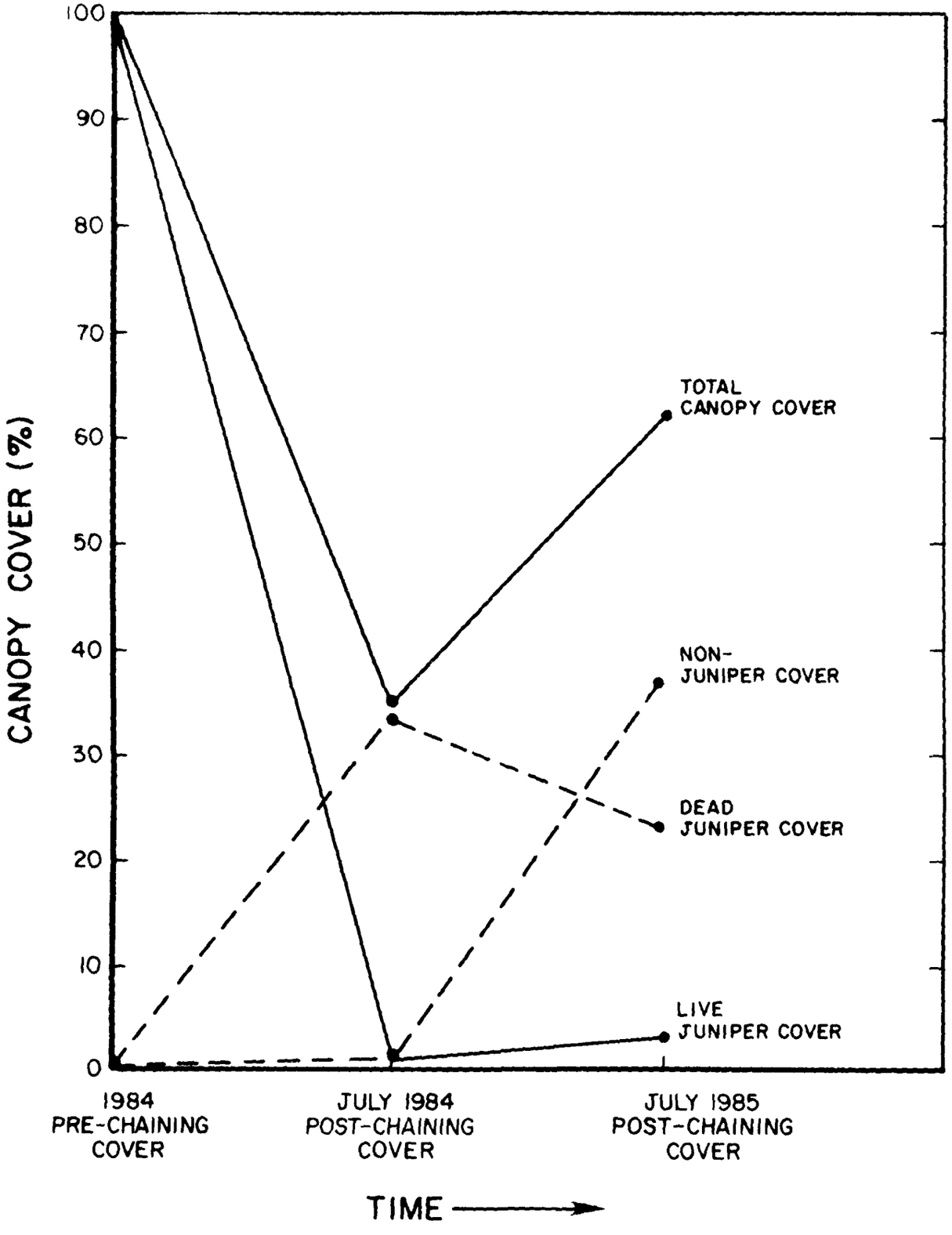

Figure 7. Changes in total canopy cover, nonjuniper canopy cover, and juniper canopy cover (dead and live).

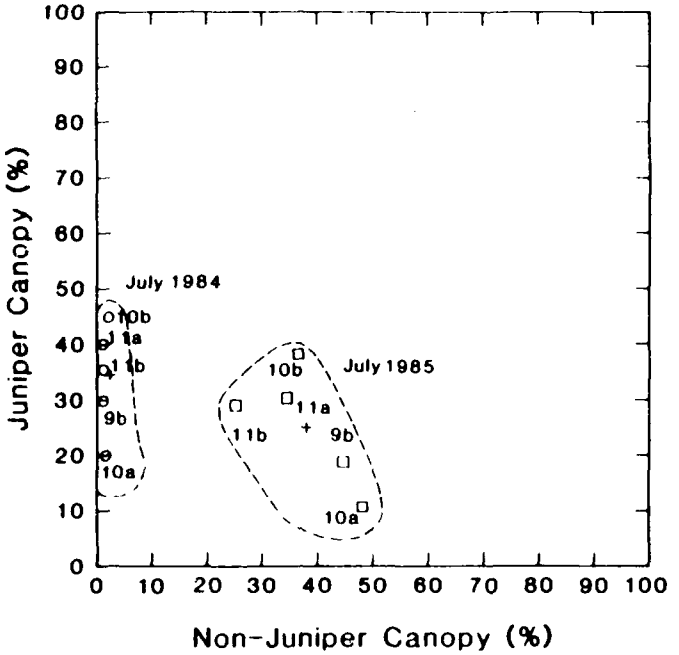

Figure 8. A bivariate analysis documenting changes in total juniper canopy cover and total nonjuniper canopy cover for each of the five transects 1 month and 13 months after chaining.

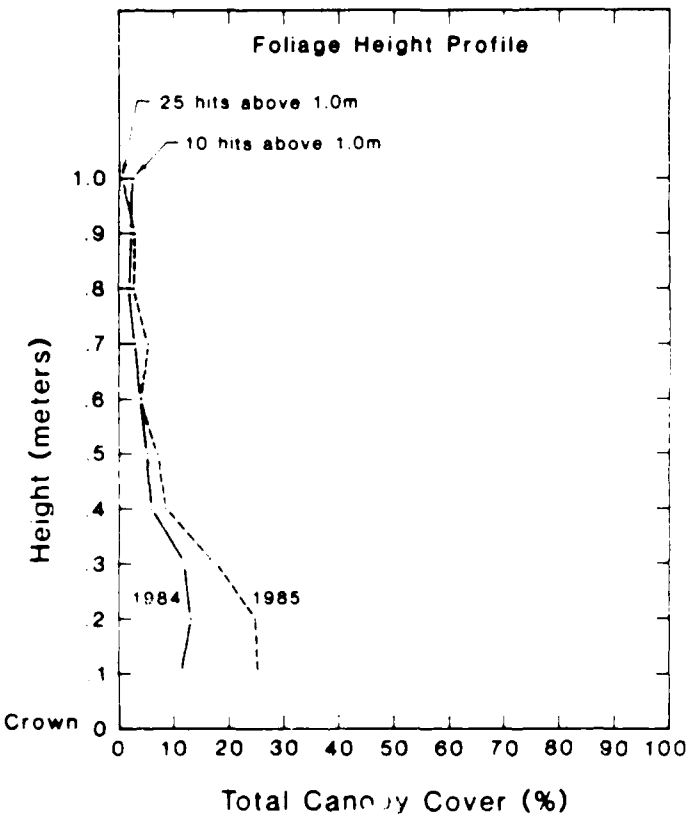

Figure 9. A foliage height profile diagram illustrating changes in canopy cover at each 0.1-m height interval 1 month and 13 months after chaining.

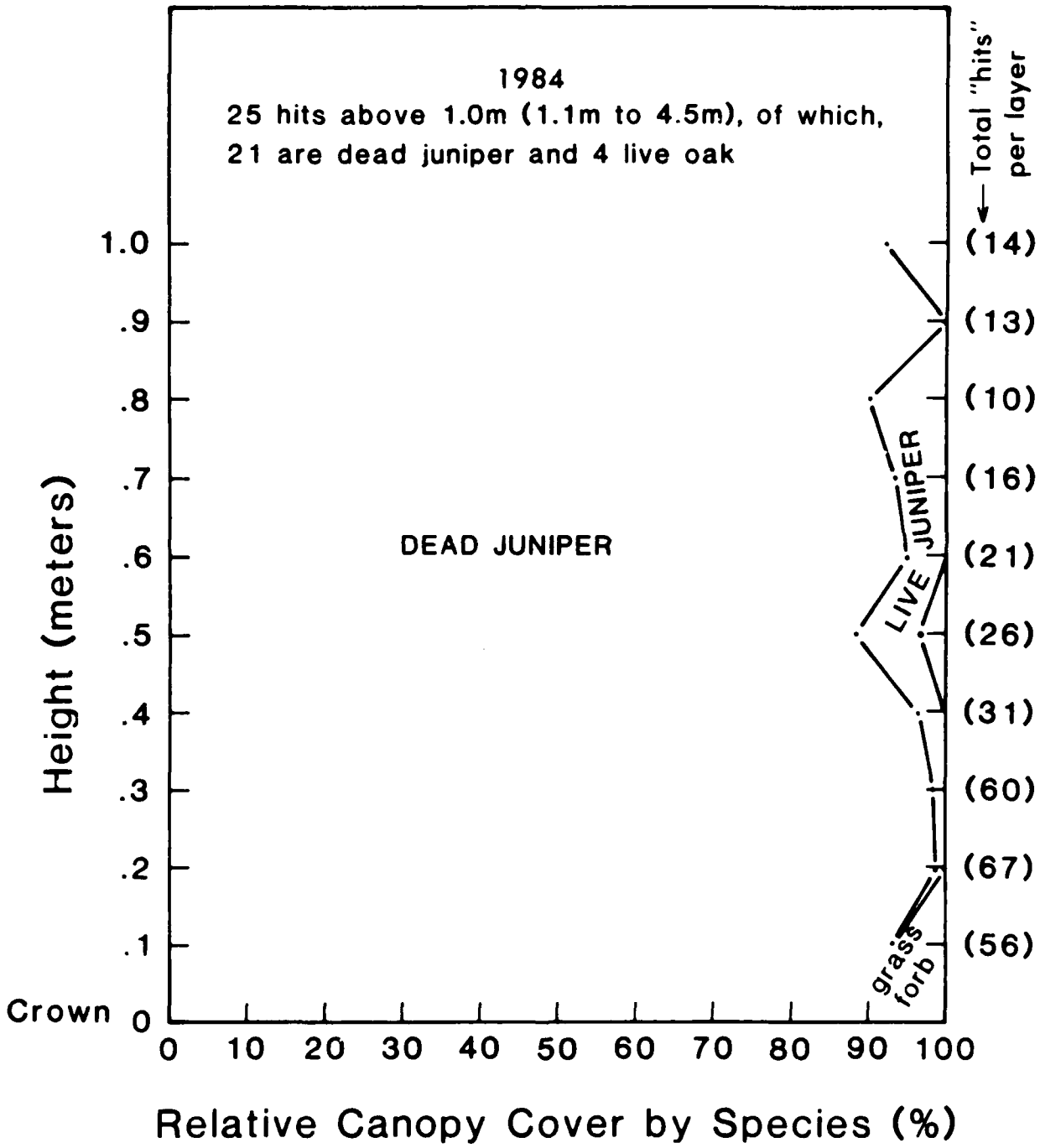

Figure 10. Relative canopy cover by species at each 0.1-m height interval in 1984 (1 month after chaining).

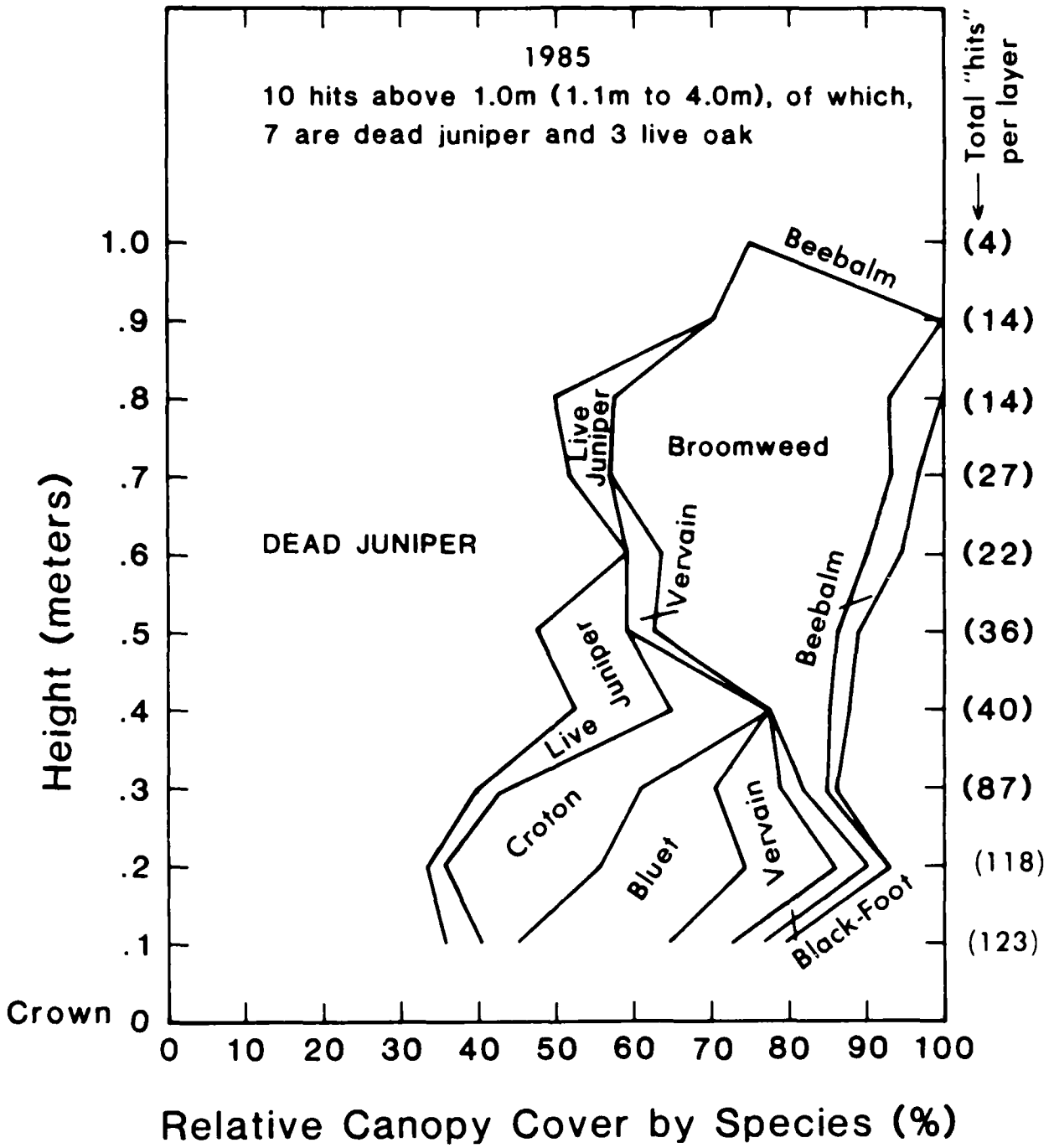

Figure 11. Relative canopy cover by species at each 0.1-m height interval in 1985 (13 months after chaining).

Figure 12. Photograph of one study site 13 months after chaining, showing the dead juniper and new herbaceous cover.

Table 1

Monthly Precipitation (mm) Recorded by Month at Gatesville, TX.* (Gatesville is about 16 km north of the chained study sites.)

Month	1951-80 Average	1984	1985
January	45.7	37.1	20.6
February	63.8	21.3	43.7
March	48.8	92.2	96.3
April	84.3	13.5	93.5
May	116.3	67.1	81.0
June	78.2	27.7	121.9
July	51.1	44.5	114.0
August	55.6	4.6	2.8
September	93.0	17.8	111.8
October	82.3	127.3	208.8
November	58.4	58.4	41.7
December	48.3	107.4	96.3
Total	825.8	618.9	1032.4

*Data are from the National Weather Service, Waco, Tx.

Table 2

Soil Erodibility Values (K of USLE), pH, and Soil Particle Size (%) Distribution in the Surface Horizon on the Study Sites

		Particle Size										
		Mechanical Analysis - Wet Sieve						Hydrometer				
Sample No.	pH	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Total Sand	Sand	Silt	Clay	Texture Class	K-Factor Value
9b	8.30	7.10	6.80	9.54	11.14	11.80	46.38	56	29	15	SA LOAM	0.26
9b	8.35	2.74	3.44	3.14	3.36	3.60	16.28	35	36	29	C LOAM	0.19
10A	8.02	3.58	5.34	4.98	3.68	2.94	20.52	48	29	23	LOAM	0.16
10A	8.00	1.76	1.60	1.46	1.30	1.64	7.76	32	53	15	SI LOAM	0.29
10B	8.30	0.94	1.58	2.18	2.44	9.36	16.50	27	38	35	C LOAM	0.22
10B	8.45	1.18	1.94	2.12	2.24	2.18	9.66	36	31	33	C LOAM	0.17
11A	8.11	1.60	1.62	1.24	1.10	1.98	7.54	29	32	39	C LOAM	0.17
11A	8.29	2.74	3.12	2.42	2.22	2.70	13.20	34	32	34	C LOAM	0.15
11B	8.24	3.14	4.14	4.60	4.14	4.76	20.78	37	37	26	LOAM	0.22
11B	8.19	0.52	1.36	1.02	1.16	1.30	5.36	34	52	14	SI LOAM	0.25
Averages	8.23	2.53	3.09	3.27	3.28	4.23	16.40	36.8	36.9	26.3		0.21

Table 3

Percent Ground Cover 1 Month (July 1984) and 13 months (July 1985) After Chaining

	Transects (1984)						Transects (1985)						
Ground Cover Variables	9b	10a	10b	11a	11b	Mean	9b	10a	10b	11a	11b	Mean	Significance *** Level
Total Bare Ground	54	35	18	18	34	31.8	46	31	17	20	35	29.8	
Exposed Bare Ground	40	32	13	13	28	25.2	20	15	3	6	18	12.4	0.001
Canopied Bare Ground	14	3	5	5	6	6.6	26	16	14	14	17	17.4	0.001
Gravel		5	-	-	-	1.0	2	10	1	-	-	2.6	
Rock		2				0.4	1	1	-		1	0.6	
Cowchips			-	1	-	0.2	-	-	-	-	-	0.0	
Deadwood	5	7	6	14	15	9.4	1	3	1	1	-	1.2	0.05
Litter (Juniper)	41	51	72	66	51	56.2	48	52	77	77	60	62.8	
Litter (Nonjuniper)		-	4	1	-	1.0	1	3	4	1	-	1.8	
Crown (basal)			-	-	-	0.0	1	-	-	1	4	1.2	
Total Ground cover	46	65	82	82	66	68.2	54	69	83	80	65	70.2	

*Exposed and canopied bare ground are subdivisions of total bare ground.

**Total ground cover is the sum of all ground cover variables except total bare ground. Total bare ground plus total ground cover is equal to 100 percent.

***Significance based on a t test of the means.

Table 4

Percent Juniper Canopy Cover 1 Month (July 1984) and 13 Months (July 1985) After Chaining

Vertical Canopy (Meters)	Transects (1984)						Transects (1985)						Significant Difference Between Years*
	9b	10a	10b	11a	11b	Mean	9b	10a	10b	11a	11b	Mean	
0.0 - 0.1	14	5	14	9	10	10.4	4	7	18	13	9	10.2	-
0.1 - 0.2	12	9	17	15	15	13.6	4	4	20	7	6	8.2	-
0.2 - 0.3	6	7	19	13	13	11.6	5	4	15	6	8	7.6	-
0.3 - 0.4	3	4	11	4	8	6.0	3	-	14	2	7	5.2	-
0.4 - 0.5	4	5	5	5	6	5.0	5	-	6	1	8	4.4	-
0.5 - 0.6	6	2	3	3	7	4.2	3	-	4	-	6	2.6	
0.6 - 0.7	3	2	4	3	4	3.2	6	1	4	-	4	3.0	-
0.7 - 0.8	-	-	2	1	7	2.0	2	-	3	1	2	1.6	-
0.8 - 0.9	3	-	1	1	8	2.6	3	-	1	2	4	2.0	-
0.9 - 1.0	1		1	1	5	1.6	-	-	1	-	2	0.6	-
1.0 - 1.1	2				6	1.6	1		1	-	2	0.8	-
1.1 - 1.2	1		1	-	5	1.4	-				1	0.2	-
1.2 - 1.3			-		3	0.6	1	-	-	-	1	0.4	-
1.3 - 1.4	1	-	-	-	1	0.4	-	-	-	-	-	-	-
1.4 - 1.5	-	-		-	-	-	-	-	-	-	-	-	-
1.5 - 1.6	1	-	-	-	-	0.2	-	-	-	-	-	-	-
Total Canopy Cover	30	19	46	40	36	34.2	19	10	39	30	29	25.4	0.01

*Significance between years based on a t test of the means.

Table 5

Percent Nonjuniper Canopy Cover 1 Month (July 1984) and 13 Months (July 1985) After Chaining

Vertical Canopy (Meters)	Transects (1984)						Transects (1985)						Significant Difference Between Years*
	9b	10a	10b	11a	11b	Mean	9b	10a	10b	11a	11b	Mean	
0.0 - 0.1	1	1		1	1	0.8	15	18	12	13	14	14.4	0.001
0.1 - 0.2							26	17	14	12	8	15.4	0.001
0.2 - 0.3							8	13	11	8	9	9.8	0.001
0.3 - 0.4							4	3	3	2	2	2.8	0.005
0.4 - 0.5		1				0.2	5	5	1	4	1	3.2	0.01
0.5 - 0.6							1	4		3	1	1.8	0.05
0.6 - 0.7							1	5	1	5		2.4	0.05
0.7 - 0.8							1	3	1	1		1.2	0.05
0.8 - 0.9								1		3		0.8	
0.9 - 1.0			1			0.2	1					0.2	
1.0 - 1.1													
1.1 - 1.2													
1.2 - 1.3													
1.3 - 1.4													
1.4 - 1.5													
1.5 - 1.6													
1.6 - 1.7													
1.7 - 1.8													
1.8 - 1.9													
1.9 - 2.0													
2.0 - 2.5													
2.5 - 3.0									1			0.2	
3.0 - 3.5			1			0.2			1			0.2	
3.5 - 4.0									1			0.2	
4.0 - 4.5	-		2			0.4							
Total Canopy Cover	1	2	2	1	1	1.4	45	49	37	35	25	38.2	0.001

*Significance between years based on a t test of the means.

Table 6

Percent Total Canopy Cover 1 Month (July 1984) and 13 Months (July 1985) After Chaining

Vertical Canopy (Meters)	Transects (1984)						Transects (1985)						Significant Difference Between Years*
	9b	10a	10b	11a	11b	Mean	9b	10a	10b	11a	11b	Mean	
0.0 0.1	15	6	14	10	11	11.2	19	25	30	26	23	24.6	0.001
0.1 0.2	12	9	17	15	15	13.6	30	21	34	19	14	23.6	0.001
0.2 0.3	6	7	19	13	13	11.6	13	17	26	14	17	17.4	0.01
0.3 0.4	3	4	11	4	8	6.0	7	3	17	4	9	8.0	-
0.4 0.5	4	6	3	5	6	5.2	10	5	7	5	9	7.2	
0.5 0.6	6	2	3	3	7	4.2	4	4	4	3	7	4.4	
0.6 0.7	3	2	4	3	4	3.2	7	6	5	5	4	5.4	
0.7 0.8			2	1	7	2.0	3	3	4	2	2	2.8	
0.8 0.9	3		1	1	8	2.6	3	1	1	5	4	2.8	
0.9 1.0	1		2	1	5	1.8	1		1		2	0.8	
1.0 1.1	2				6	1.6	1		1		2	0.8	-
1.1 1.2	1		1		5	1.4					1	0.2	
1.2 1.3					3	0.6	1				1	0.4	-
1.3 1.4					1	0.2							
1.4 1.5													
1.5 1.6	1					0.2							
1.6 1.7													
1.7 1.8													
1.8 1.9													-
1.9 2.0													
2.0 2.5													
2.5 3.0									1			0.2	-
3.0 3.5			1			0.2			1			0.2	-
3.5 4.0									1			0.2	-
4.0 4.5			2			0.4						-	-
Total Canopy Cover	31	23	47	33	37	15.4	61	59	76	63	53	62.4	0.001

Table 7

Botanical (Species) Compositon and Percent Canopy Cover for Each 0.1-Meter Height Interval (July 1984 and July 1985)

Height Interval (0 to 0.1 m)

Species Common Name/Scientific Name	Transects (1984) 9b	10a	10b	11a	11b	Mean	Transects (1985) 9b	10a	10b	11a	11b	Mean
Texas Grama *Bouteloua rigidiseta*	-	-	-	-	-	-	1	-	-	-	-	0.2
Buffalograss *Buchloe dactyloides*	-	-	-	-	1	0.2	-	-	-	1	2	0.6
Croton *Croton texensis* and *monanthogynus*	-	-	-	-	-	-	-	1	-	2	1	0.8
Prairie Bundleflower *Desmanthus leptolobus*	-	-	-	-	-	-	1	-	3	-	-	0.8
Hairy Tridens *Erioneuron pilosum*	-	-	-	-	-	-	-	-	-	-	1	0.2
Prairie Euphorb *Euphorbia missurica*	-	-	-	-	-	-	-	-	1	-	-	0.2
Prairie Bluet *Hedyotis nigricans*	-	-	-	-	-	-	10	9	4	-	-	4.6
Pasture Heliotrope *Heliotropium tenellum*	-	-	-	-	-	-	-	1	-	-	-	0.2
Ashe Juniper (dead) *Juniperus ashei*	14	5	14	9	10	10.4	4	7	15	11	8	9.0
Ashe Juniper (live) *Juniperus ashei*	-	-	-	-	-	-	-	-	3	2	1	1.2
Prickly Lettuce *Lactuca serriola*	-	-	-	-	-	-	-	-	-	1	-	0.2
White Honeysuckle *Lonicera albiflora*	-	-	-	-	-	-	-	-	-	1	-	0.2
Plains Black foot *Melampodium leucanthum*	-	-	-	-	-	-	1	1	-	-	3	1.0
Crownseed *Pectis angustifolia*	-	-	-	-	-	-	-	-	1	-	-	0.2
Redseed Plantain *Plantago rhodosperma*	-	-	-	-	-	-	-	1	-	-	-	0.2
Texas Salvia *Salvia texana*	-	-	-	-	-	-	-	1	-	1	-	0.4
Dakota Vervain *Verbena bipinnatifida*	-	-	-	-	-	-	1	-	2	4	3	2.0
Common Broomweed *Xanthocephalum dracunculoides*	-	-	-	-	-	-	1	-	-	1	-	0.4
Unknown forbs	1	-	-	-	-	0.2	-	2	-	1	4	1.4
Unknown grasses	-	1	-	1	-	0.4	-	1	1	-	-	0.4
Unknown sedge	-	-	-	-	-	-	-	1	-	1	-	0.4

Total 1984 Canopy Cover = 11.2% Total 1985 Canopy Cover = 24.6%

Table 7 (Cont'd)

Species Common Name/Scientific Name	Height Interval (0.1 – 0.2 m)											
	Transects (1984)						Transects (1985)					
	9b	10a	10b	[illegible]	11b	Mean	9b	10a	10b	11a	11b	Mean
Croton *Croton texensis* and *monanthogynus*							4	8	3	7	3	5.0
Prairie Euphorb *Euphorbia missurica*								1	1	-	-	0.4
Hedeoma drummondii							1		-	-	-	0.2
Prairie Bluet *Hedyotis nigricans*							8	5	8	-	-	4.2
Ashe Juniper (dead) *Juniperus ashei*	12	7	17	15	15	13.2	4	4	19	7	5	7.8
Ashe Juniper (live) *Juniperus ashei*		2				0.4	-		1	-	1	0.4
Plains Black foot *Melampodium leucanthum*							4	1	-	-	1	1.2
Crownseed *Pectis angustifolia*									1	-	-	0.2
Redseed Plantain *Plantago rhodosperma*								1	-	-	-	0.2
Slender Greenthread *Thelesperma simplicifolium*							-	1		-	-	0.2
Dakota Vervain *Verbena bipinnatifida*							7	1	1	2	2	2.6
Western Ironweed *Vernonia baldwinii*						-			-	1	-	0.2
Common Broomweed *Xanthocephalum dracunculoides*										1	2	0.6
Unknown forbs							1		-	1	-	0.4

Total 1984 Canopy Cover = 13.6% Total 1985 Canopy Cover = 23.6%

Table 7 (Cont'd)

Height Interval (0.2 to 0.3 m)

Species Common Name/Scientific Name	Transects (1984) 9b	10a	10b	11a	11b	Mean	Transects (1985) 9b	10a	10b	11a	11b	Mean
Croton *Croton texensis* and *monanthogynus*	-	-	-	-	-	-	2	1	5	5	3	3.2
Prairie Euphorb *Euphorbia missurica*	-	-	-	-	-	-	-	2	1	-	1	0.8
Hedeoma drummondii	-	-	-	-	-	-	1	-	-	-	-	0.2
Prairie Bluet *Hedyotis nigricans*	-	-	-	-	-	-	3	3	2	-	-	1.6
Pasture Heliotrope *Heliotropium tenellum*	-	-	-	-	-	-	-	1	-	-	1	0.4
Ashe Juniper (dead) *Juniperus asheı*	5	7	19	13	13	11.4	5	4	14	6	6	7.0
Ashe Juniper (live) *Juniperus asheı*	1	-	-	-	-	0.2		-	1	-	2	0.6
Plains Black foot *Melampodium leucanthum*	-	-	-	-	-	-	-	-	-	-	2	0.4
Lemmon Beebalm *Monarda citriodora*	-	-	-	-	-	-	-	-	1	-	-	0.2
Live Oak *Quercus fusiformis*	-	-	-	-	-	-	-	1	-	-	-	0.2
Dakota Vervain *Verbena bipinnatifida*	-	-	-	-	-	-	2	1	1	1	2	1.4
Cocklebur *Xanthium strumarium*	-	-	-	-	-	-	-	-	-	1	-	0.2
Common Broomweed *Xanthocephalum dracunculoides*	-	-	-	-	-	-	-	1	-	1	-	0.4
Unknown forbs	-	-	-	-	-	-	-	3	1	-	-	0.8

Total 1984 Canopy Cover = 11.6% Total 1985 Canopy Cover = 17.4%

Table 7 (Cont'd)

Height Interval (0.3 to 0.4 m)

Species Common Name/Scientific Name	Transects (1984) 9b	10a	10b	11a	11b	Mean	Transects (1985) 9b	10a	10b	11a	11b	Mean
Croton *Croton texensis* and *monanthogynus*	-	-	-	-	-	-	1	1	1	1	1	1.0
Narrowleaf Sumpweed *Iva angustifolia*	-	-	-	-	-	-	1	-	-	-	-	0.2
Ashe Juniper (dead) *Juniperus ashei*	3	3	11	4	8	5.8	3	-	13	2	3	4.2
Ashe Juniper (live) *Juniperus ashei*	-	1	-	-	-	0.2	-	-	1	-	4	1.0
White Honeysuckle *Lonicera albiflora*	-	-	-	-	-	-	-	-	-	1	-	0.2
Lemmon Beebalm *Monarda citriodora*	-	-	-	-	-	-	-	-	1	-	-	0.2
Common Broomweed *Xanthocephalum dracunculoides*	-	-	-	-	-	-	1	1	-	-	1	0.6
Unknown Forbs	-	-	-	-	-	-	1	1	1	-	-	0.6

Total 1984 Canopy Cover = 6.0% Total 1985 Canopy Cover = 8.0%

Height Interval (0.4 to 0.5 m)

Species Common Name/Scientific Name	Transects (1984) 9b	10a	10b	11a	11b	Mean	Transects (1985) 9b	10a	10b	11a	11b	Mean
Narrowleaf Sumpweed *Iva angustifolia*	-	-	-	-	-	-	2	-	-	-	-	0.4
Ashe Juniper (dead) *Juniperus ashei*	4	3	5	5	6	4.6	4	-	6	1	5	3.2
Ashe Juniper (live) *Juniperus ashei*	-	2	-	-	-	0.4	1	-	-	-	3	0.8
Lemmon Beebalm *Monarda citriodora*	-	-	-	-	-	-	-	-	-	1	-	0.2
Live Oak *Quercus fusiformis*	-	1	-	-	-	0.2	-	-	-	-	-	-
Dakota Vervain *Verbena bipinnatifida*	-	-	-	-	-	-	-	-	-	1	-	0.2
Common Broomweed *Xanthocephalum dracunculoides*	-	-	-	-	-	-	3	4	-	2	1	2.0
Unknown Forbs	-	-	-	-	-	-	-	1	1	-	-	0.4

Total 1984 Canopy Cover = 5.2% Total 1985 Canopy Cover = 7.2%

Table 7 (Cont'd)

Height Interval (0.5 0.6 m)

Species Common Name/Scientific Name	Transects (1984) 9b	10a	10b	11a	11b	Mean	Transects (1985) 9b	10a	10b	11a	11b	Mean
Ashe Juniper (dead) *Juniperus ashei*	6	1	3	3	7	4.0	3		4		6	2.6
Ashe Juniper (live) *Juniperus ashei*	-	1			-	0.2			-			
Lemmon Beebalm *Monarda citriodora*											1	0.2
Live Oak *Quercus fusiformis*	-			-	-		1	-	-		-	0.2
Dakota Vervain *Verbena bipinnatifida*	-		-	-	-		-	-	1		-	0.2
Common Broomweed *Xanthocephalum dracunculoides*					-		1	3	-	2	-	1.2

Total 1984 Canopy Cover = 4.2% Total 1985 Canopy Cover = 4.4%

Height Interval (0.6 0.7 m)

Species Common Name/Scientific Name	Transects (1984) 9b	10a	10b	11a	11b	Mean	Transects (1985) 9b	10a	10b	11a	11b	Mean
Ashe Juniper (dead) *Juniperus ashei*	3	1	4	3	4	3.0	6	1	3	-	4	2.8
Ashe Juniper (live) *Juniperus ashei*		1			-	0.2			1		-	0.2
Lemmon Beebalm *Monarda citriodora*					-	-		-	1	-	-	0.2
Common Broomweed *Xanthocephalum dracunculoides*	-	-	-	-	-			5		5	-	2.0
Unknown Forb						-	1				-	0.2

Total 1984 Canopy Cover = 3.2% Total 1985 Canopy Cover = 5.4%

Table 7 (Cont'd)

Height Interval (0.7 - 0.8 m)

Species Common Name/Scientific Name	Transects (1984) 9b	10a	10b	11a	11b	Mean	Transects (1985) 9b	10a	10b	11a	11b	Mean
Ashe Juniper (dead) *Juniperus ashei*	-	-	1	1	7	1.8	2	-	3	-	2	1.4
Ashe Juniper (live) *Juniperus ashei*	-	-	1	-	-	0.2	-	-	-	1	-	0.2
Lemmon Beebalm *Monarda citriodora*	-	-	-	-					1	-	-	0.2
Common Broomweed *Xanthocephalum dracunculoides*	-	-	-	-	-	-	1	3	-	1	-	1.0
	Total 1984 Canopy Cover = 2.0%						Total 1985 Canopy Cover = 2.8%					

Height Interval (0.8 - 0.9 m)

Species Common Name/Scientific Name	Transects (1984) 9b	10a	10b	11a	11b	Mean	Transects (1985) 9b	10a	10b	11a	11b	Mean
Ashe Juniper (dead) *Juniperus ashei*	3	-	1	1	8	2.6	3	-	1	2	4	2.0
Common Broomweed *Xanthocephalum dracunculoides*	-	-	-	-	-	-	-	1	-	3		0.8
	Total 1984 Canopy Cover = 2.6%						Total 1985 Canopy Cover = 2.8%					

Height Interval (0.9 - 1.0 m)

Species Common Name/Scientific Name	Transects (1984) 9b	10a	10b	11a	11b	Mean	Transects (1985) 9b	10a	10b	11a	11b	Mean
Ashe Juniper (dead) *Juniperus ashei*	1	-	1	1	5	1.6	-	-	1	-	2	0.6
Lemmon Beebalm *Monarda citriodora*	-	-	-	-	-	-	1	-	-	-	-	0.2
Live Oak *Quercus fusiformis*	-	-	1	-	-	0.2	-	-	-	-	-	
	Total 1984 Canopy Cover = 1.8%						Total 1985 Canopy Cover = 0.8%					

Table 8

Calculation of Slope Gradients and Lengths (LS Values of USLE) on the Three Study Sites

Transect	Slope Gradient (%)	Slope Length (Meters)	LS Value
9b	4.9	110	0.95
	2.1	90	0.29
10a	4.0	140	0.73
	3.5	120	0.57
10b	3.5	120	0.57
	2.0	110	0.29
11a	0.8	90	0.14
	3.7	90	0.55
11b	3.7	90	0.55
	2.8	140	0.43
Averages	3.1%	110	0.51

Table 9

Changes in Soil Erosion Estimates Before Chaining, 1 Month After Chaining (1984), and 13 Months After Chaining (1985)

	Soil Erosion Estimates		
	Before Dozing/ Chaining	1 Month After Dozing/Chaining	13 Months After Dozing/Chaining
Litter	100.00	57.2	64.6
Crown		0	1.2
Deadwood		9.4	1.2
Rock		0.4	0.6
Gravel		1.0	2.6
Cowchips		0.2	0
Total Ground Cover	100.00	68.2	70.2
Total Canopy Cover	100.00	35.4	62.4
Cover (C) Factor	(.01)	(.06)	(.05)
Estimated Erosion by Category A = (R)(K)(LS)(C) A = (280)(.21)(.51)(C)	0.30	1.80	1.50

Allowable soil loss (T) 5.00 tons/acre/year

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